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The trophic role of cave shrimps of the genus *Typhlatya* seen through stable isotope eyes

Brenda Durán[1,2], Fernando Álvarez[2]

1 *Posgrado en Ciencias Biológicas, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510 Ciudad de México, Mexico City, Mexico* **2** *Colección Nacional de Crustáceos, Instituto de Biología, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510 Ciudad de México, Mexico City, Mexico*

Corresponding author: Fernando Álvarez (falvarez@unam.mx)

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Abstract

With the aim of describing the isotopic niche of the anchialine shrimps of the genus *Typhlatya* from the Yucatan Peninsula (YP) we analyze a dataset that includes three of the four species present in the region using published and new $\delta^{13}C$ and $\delta^{15}N$ values. *Typhlatya* shrimps are recognized as ecologically important in the anchialine food web due to their ample distribution, relatively high abundance and feeding characteristics. The variation in $\delta^{13}C$ values shows that *Typhlatya* shrimps cover almost the complete interval of the whole anchialine community reflecting the different nutrient sources they can feed on; the three species separately have $\delta^{13}C$ ranges that partially overlap, becoming more negative starting with *T. mitchelli*, followed by *T. dzilamensis* and *T. pearsei*. The $\delta^{13}C$ ranges for *T. mitchelli* and *T. pearsei* from four cenotes did not change between the rainy and dry seasons. By region, the $\delta^{13}C$ ranges for the whole anchialine community in the Ring of Cenotes are narrower and less negative than those from the Caribbean Cave Area, reflecting the different geomorphology and hydrology of the two regions. The isotopic niches of *T. mitchelli* and *T. pearsei*, the two dominant species in the freshwater lens, overlap around 20% leaving an ample margin for coexistence. *Typhlatya pearsei* has the most negative $\delta^{13}C$ values which are consistent with feeding on microbial biomass, including methanotrophic bacteria. The isotopic niches of the three *Typhlatya* species studied although somewhat variable, are well defined and compose a well structured community.

Keywords

Anchialine, atyid shrimps, $\delta^{13}C$, $\delta^{15}N$, Isotopic niche, Yucatan Peninsula

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Introduction

The family Atyidae is composed of primary freshwater shrimps characterized by their modified first and second pairs of pereopods for filtering, rather than having the typical chelae adapted for cutting and tearing (Chace 1992). The ability to filter feed may have allowed atyid shrimps to survive in nutrient poor environments such as river headwaters or phreatic waters, where they can filter tiny particles or scrape the biofilm attached to rocks or on the sediment for food. The successful colonization of subterranean waters, which are often oligotrophic, by several lineages within the family (e.g., 15 of 42 genera in the Atyidae have cave dwelling species (De Grave and Fransen 2011)) is probably linked to this feeding mode.

The Atyidae, within the Caridea, is an old group probably arising in the Permo-Triassic boundary around 250 mya. The various lineages with stygobitic or stygophilic species represent independent invasions of the cave environment that occurred at different times depending on the geologic history of the landmass where they occur (von Rintelen et al. 2012). In particular, the clade that groups species that currently inhabit anchialine caves may have evolved in late Jurassic or early Cretaceous times, when it possibly occupied coastal areas of the ancient Tethys Sea (von Rintelen et al. 2012; Jurado-Rivera et al. 2017). The contemporary distribution of the genera *Typhlatya*, in coastal areas of the Greater Caribbean, Mediterranean Sea, Ascension and Galapagos Islands, and Indian Ocean; *Typhlopatsa* in Madagascar; and *Stygiocaris* in Australia, is consistent with the Tethyan origin hypothesis for this group (Alvarez et al. 2005; Botello et al. 2013; Jurado-Rivera et al. 2017).

The relevance of their evolutionary history resides in their role as primary consumers in nutrient-poor environments. Since these shrimps have specialized in feeding on bacterial growths or biofilms in addition to suspended food particles, they can generate biomass that is then consumed by other organisms at higher trophic levels. In this scenario, we can hypothesize that once *Typhlatya* shrimps invade a cave, they might become the crucial element that connects primary producers or particulate organic matter with higher trophic levels thus facilitating the arrival of other species. Brankovits et al. (2017) highlighted the critical role of *Typhlatya* shrimps in caves of the Yucatan Peninsula (YP) for the functioning of a newly described chemoautotrophic route. It has been proposed that *Typhlatya* shrimps feed on minute particles or bacterial growths composed of nitrifying (Pohlman et al. 1997) and/or methanotrophic bacteria (Brankovits et al. 2017). Trejo-Ventura et al. (2023) examined the feeding apparatus displayed in the first two pereopods of *Typhlatya* shrimps from the YP showing that the setal arrangement is clearly adapted for scraping and different from that of epigean filter feeding species, which is consistent with the commonness of bacterial mats and the low quantity of suspended food particles in the anchialine environment. Nevertheless, the YP anchialine fauna includes other species that could also feed on bacterial mats such as the thermosbaenacean *Tulumella unidens*; however, these are rare and occur in very low numbers to have the central role of *Typhlatya* in the trophic web (Benítez et al. 2019).

Typhlatya shrimps could thus be considered as keystone species in the ecosystem as they introduce nutrients to the anchialine trophic web by taking advantage of microbial production, either from nitrifying bacteria acting on plant debris or methanotrophic bacteria that consume methane from the water column (Brankovits et al. 2017; Durán and Álvarez 2025) (Fig. 1). Their important trophic role is underscored by their wide distribution along the northern section of the peninsula in the states of Campeche, Yucatan and Quintana Roo (Alvarez et al. 2015, 2023); where three of the four Mexican *Typhlatya* species are relatively common. These two attributes (e.g., being a critical link to incorporate organic matter into the ecosystem and their wide distribution and abundance) pose interesting questions about how their role can be modified depending on: 1) the species composition found in each cave system, 2) the changes in the water masses due to the rainy and dry seasons and 3) the geomorphology and location of the cave (i.e., close vs far away from the coastline). To explore these questions, we chose to analyze stable isotope data as it reflects the possible food sources that an organism is feeding on.

In a previous study Durán and Álvarez (2025) found in one cave (Cenote Vaca Ha) that the $\delta^{13}C$ values for *Typhlatya mitchelli* and *T. pearsei* varied relatively little annually and seasonally, but these values contrast with our own results from other caves in the YP as well as with those reported by other authors (Brankovits et al. 2017; Chávez-Solís et al. 2020). To test these ideas, here we combine all published isotope data for *Typhlatya* shrimps in the YP with newly generated $\delta^{13}C$ and $\delta^{15}N$ measurements to: 1) compare trophic niches among species, 2) test for seasonal stability, and 3) examine geographic effects linked to cave geomorphology.

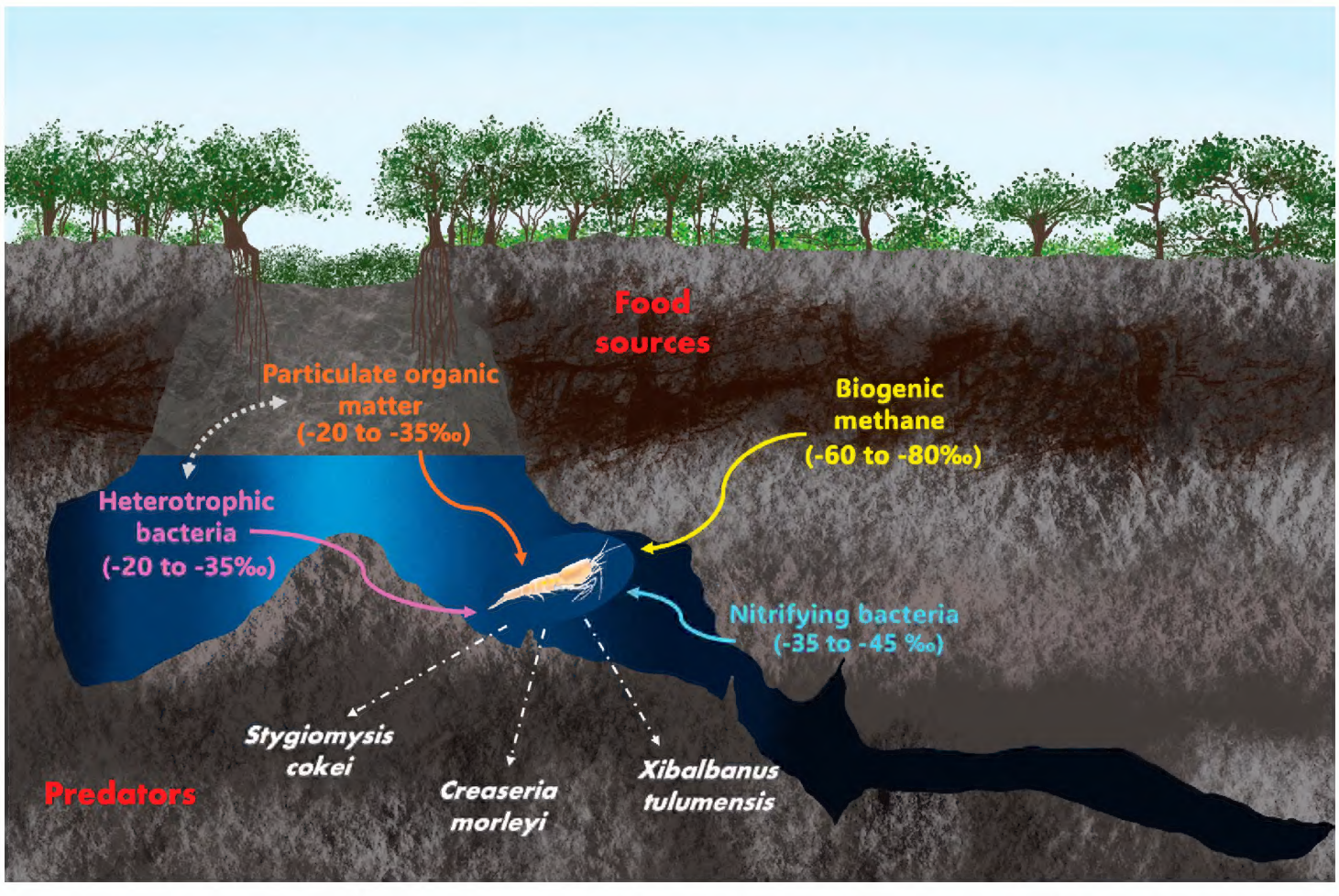

Figure 1. Schematic representation of the trophic role of *Typhlatya* shrimps in the Yucatan Peninsula depicting food sources with their $\delta^{13}C$ values and species that prey on *Typhlatya* shrimps.

Materials and methods

Building the dataset

We searched for all published data on carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopic analyses performed on the tissue of *Typhlatya* shrimps from the YP. In some instances, authors reported values for "*Typhlatya*" without specifying the species (e.g., Pohlman et al. 1997), or for the whole anchialine community without specifying species but including one or several species of *Typhlatya* (e.g., Brankovits et al. 2017). The sources and associated data for each isotope value used are described in Table 1, the complete dataset is in Suppl. material 1. We used all available data (published and newly generated) noting in what season (i.e., dry or rainy) the samples were collected.

The new isotopic values ($\delta^{13}C$, $\delta^{15}N$) for *Typhlatya* spp. from the YP were obtained from samples collected between November 2022 and March 2023 (Collecting permit PPF/DGOPA-084/22, SAGARPA, México). The organisms were collected by two cave divers using 50 ml sterile vials and frozen at -4 °C in the field; the samples were taken to the laboratory, defrosted at room temperature and dried at 60 °C for 48 h and then grinded until a fine powder was obtained. To remove inorganic carbon, the samples were placed in silver capsules within a Teflon microtiter plate and exposed to HCl fumes inside a glass desiccator with four beakers with 25 ml of 37% HCl for 24 h (Harris et al. 2001). After the acid treatment the samples were placed in tin capsules and analyzed in a mass spectrometer (Isotopic Ratio Spectrometer, Isoprime 100TM, CF-EA) at the Stable Isotopes Laboratory of the Geotop Center at UQAM (Université du Québec à Montréal, Montréal, Québec, Canada). Carbon and nitrogen isotope ratios are expressed as $\delta^{13}C$ (‰) relative to Vienna Pee Dee Belemnite standard and as $\delta^{15}N$ (‰) relative to air.

The isotopic values generated in this study correspond to *T. mitchelli* and *T. pearsei* collected both during the rainy and dry seasons in four cenotes: Noh-Mozon and

Table 1. Data sources of isotopic data (^{13}C, ^{15}N) for *Typhlatya* species from the Yucatan Peninsula.

Species	Locality	Source	Isotope
Typhlatya sp.	Bang	Brankovits et al. 2017	^{13}C
Typhlatya mitchelli	Tza Itza	Chávez-Solís et al. 2020	^{13}C
	Mayan Blue	Pohlman et al. 1997	^{13}C, ^{15}N
	Nohoch Na Chich	This study	^{13}C, ^{15}N
	Vaca Ha	Durán & Álvarez 2025	^{13}C, ^{15}N
	Buenavista	This study	^{13}C, ^{15}N
	Noh Mozón	This study	^{13}C, ^{15}N
	Kankirixché	This study	^{13}C, ^{15}N
	X Batún	This study	^{13}C, ^{15}N
Typhlatya pearsei	Vaca Ha	Durán & Álvarez 2025	^{13}C, ^{15}N
	Noh Mozon	This study	^{13}C, ^{15}N
	Noh Mozon	Chávez-Solís et al. 2020	^{13}C
Typhlatya dzilamensis	Ponderosa	Chávez-Solís et al. 2020	^{13}C

Kankirixche (around the city of Mérida, part of the Ring of Cenotes); as well as Vaca Ha and Nohoch Nah Chich (near the town of Tulum, within the Caribbean Cave Area) (Álvarez et al. 2023). Additionally, we analyzed samples assigned to *T. mitchelli* from Cenote X Batun (Ring of Cenotes) and Cenote Buenavista (Caribbean Cave Area).

Data analysis

Initially, the complete range of $\delta^{13}C$ values for each cenote were plotted to visualize the variation among sites. To test for differences among *Typhlatya* species, we first tested the normality of $\delta^{13}C$ values for each species using the Shapiro-Wilks test. Because normality was rejected in all cases, we applied a non-parametric Kruskal-Wallis test followed by Dunn's multiple comparison to identify which species differed significantly.

Seasonal variation (rainy versus dry seasons), was evaluated for two species in four cenotes. Given the reduced sample size, we again tested for normality using a Shapiro-Wilks test, and after rejecting normality used a Wilcoxon signed-rank test. Paired comparisons were conducted for each species within each cenote.

The $\delta^{13}C$ – $\delta^{15}N$ isotopic niches for *T. mitchelli* and *T. pearsei* were generated using convex hulls. Plots were generated using the functions "geom-convexhull" and "overlap-area", included in ggplot2 V4.0.1 (Wickham 2016). We selected the convex hull approach over Bayesian standard ellipses because each hull incorporates all individual data points, providing a precise depiction of the full isotopic breadth of each species. In contrast, standard ellipses are more appropriate for comparing central tendency or community-level niche widths (Layman et al. 2012).

Finally, $\delta^{13}C$–$\delta^{15}N$ values were used to calculate three community-level trophic metrics (Layman et al. 2007): nitrogen range (NR), carbon range (CR), and total hull area (TA). NR reflects vertical trophic structure, with larger values indicating a greater number of trophic levels or higher trophic diversity. CR represents variation at the base of the food web, where larger values suggest a broader diversity of basal resources. TA reflects the overall trophic niche space occupied by a species and is influenced by individuals with extreme $\delta^{15}N$ and $\delta^{13}C$ values; thus, TA generally increases with NR and CR.

Results

A total of four studies reported $\delta^{13}C$ values for three *Typhlatya* species across seven cenotes, and in this study we present new data for *T. mitchelli* and *T. pearsei* from five cenotes (Table 1). Only two previous studies reported $\delta^{15}N$ values for *T. mitchelli* and *T. pearsei* from two cenotes; here, we expand the coverage by adding $\delta^{15}N$ values for these two species from five cenotes (Table 1). Four studies reported $\delta^{13}C$ – $\delta^{15}N$ values for the anchialine community or for *Typhlatya* spp. (Pohlman et al. 1997; Pohlman 2011; Brankovits et al. 2017; Durán and Álvarez 2025).

The $\delta^{13}C$ values for all anchialine species across all cenotes in the YP ranged from -20.08 to -55.48 (Fig. 2), while $\delta^{15}N$ values spanned -0.56 to 14.12. The range of

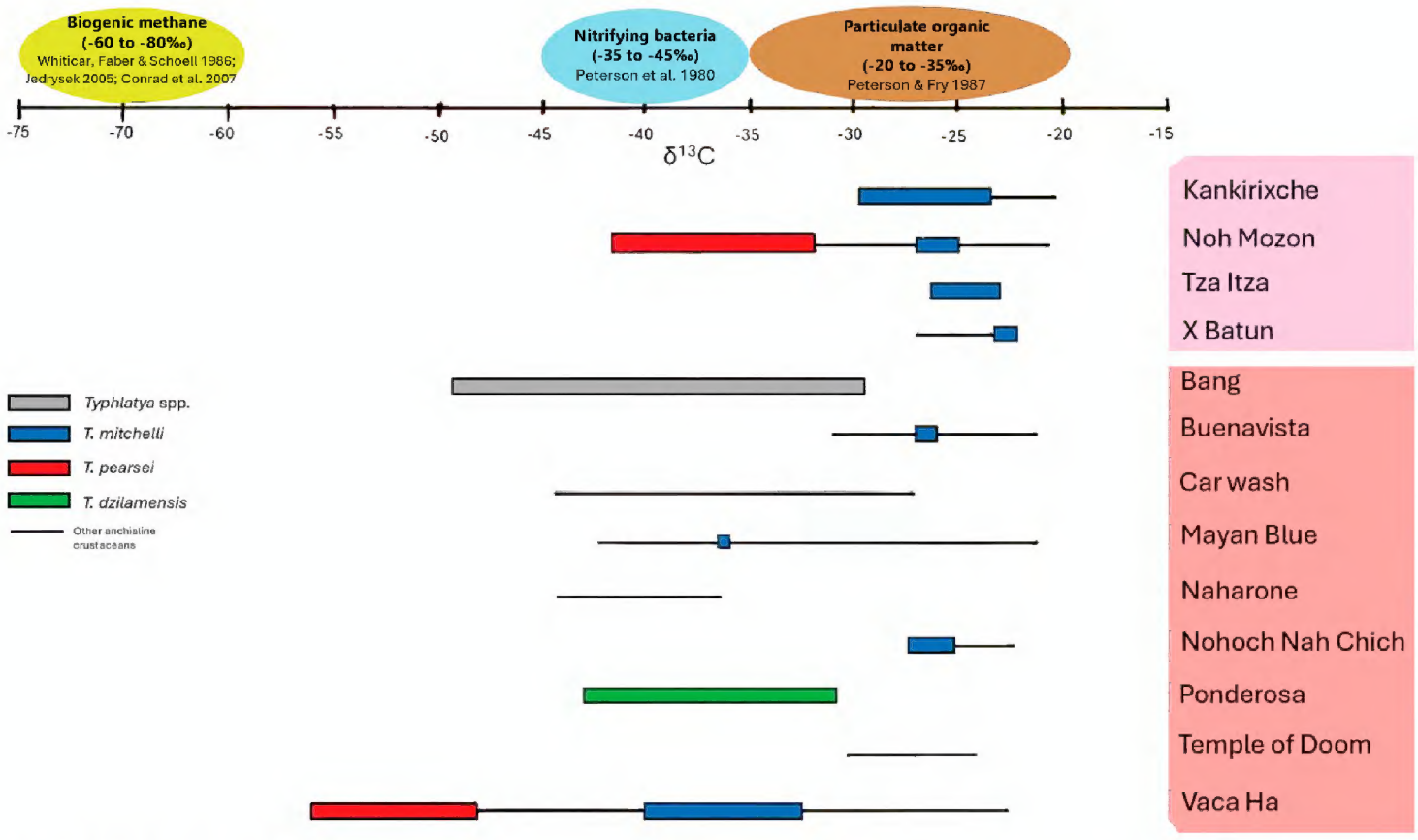

Figure 2. Ranges of $\delta^{13}C$ values for three *Typhlatya* species (indicated by coloured boxes), for unidentified *Typhlatya* and for other anchialine species (indicated by a line) for 13 cenotes in the Yucatan Peninsula. The top four cenotes in the pink box are located in the Ring of Cenotes, while the bottom nine in the orange box are located in the Caribbean Cave Area. On the top are the proposed $\delta^{13}C$ ranges for the possible food sources.

$\delta^{13}C$ for *Typhlatya* species was slightly narrower (-22.31 to -55.48). At the species level, $\delta^{13}C$ values show a progression from less to more negative values: *T. mitchelli* (-22.31 to -39.65), followed by *T. dzilamensis* (-31.26 to -43.78), and *T. pearsei* (-32.04 to -55.48) (Fig. 3). Unidentified *Typhlatya* individuals from cenote Bang showed $\delta^{13}C$ values between -29.27 and -49.65 (Figs 2, 3; Brankovits et al. 2017), a range consistent with any of the three species considered – or potentially with a yet undescribed lineage detected through molecular analyses (Álvarez et al. 2015; Ballou et al. 2022). Statistical comparison revealed significant differences among species (Kruskal-Wallis H = 28.264, $p = 3.197 \times 10^{-6}$), with *T. mitchelli* differing from *T. pearsei* and from individuals identified only to genus level (Table 2).

The comparison of $\delta^{13}C$ values between the dry and rainy seasons was conducted for *Typhlatya mitchelli* in four cenotes (Vaca Ha, Nohoch Nah Chich, Kankirixche, Noh Mozon) and for *T. pearsei* in two (Vaca Ha, Noh Mozon) (Fig. 4). Paired Wilcoxon signed-rank tests, conducted separately for each species and cenote, revealed no significant seasonal differences in any case ($p > 0.05$; Fig. 4; Suppl. material 2).

Geographically, cenotes in the Ring of Cenotes (Kankirixche, Noh Mozon, Tza Itza, X Batun) exhibited narrower $\delta^{13}C$ ranges for *Typhlatya* species (-22.79 to -41.01, $\bar{x}$ = -28.65) than those in the Caribbean Cave Area (-23.45 to -55.48, $\bar{x}$ = -36.20) (Fig. 2). Within the Ring of Cenotes, Cenote X Batun showed the least negative $\delta^{13}C$ values (-22.31 to -22.4) based solely on *T. mitchelli.* In contrast, cenote Vaca Ha in the Caribbean Cave Area displayed the highest values (-32.36 to -55.48), reflecting the

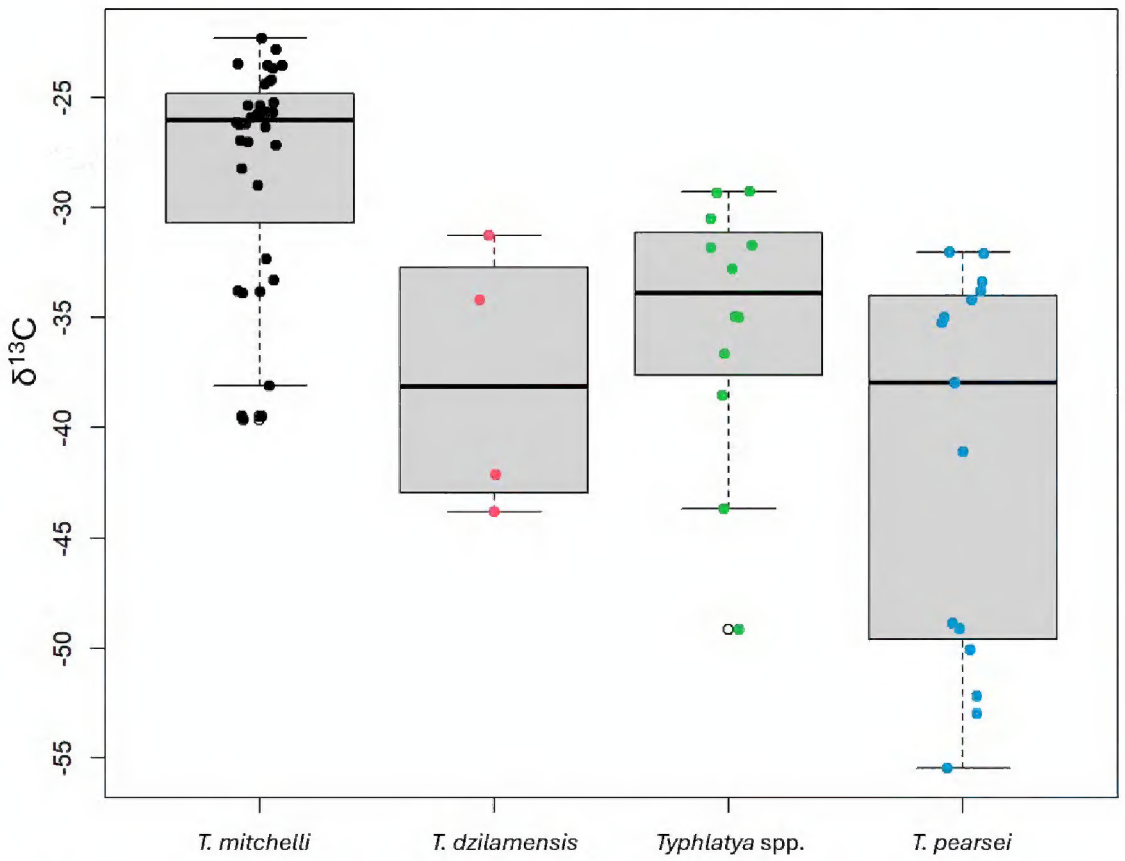

Figure 3. Box plot (median, lower and upper quartiles, and maximum and minimum values) of the $\delta^{13}C$ range for three species of *Typhlatya* and for samples identified to genus only including data points.

Table 2. Results of the Dunn multiple comparison test conducted on the $\delta^{13}C$ ranges of the species of *Typhlatya*.

Species	Mean rank difference	p
T. mitchelli – *T. dzilamensis*	25.7368	0.0880
T. pearsei – *T. dzilamensis*	-3.7000	1.0000
Typhlatya spp. – *T. dzilamensis*	6.5000	1.0000
T. pearsei – *T. mitchelli*	-29.4368	**9e-06**
Typhlatya spp. – *T. mitchelli*	-19.2368	**0.0227**
Typhlatya spp. – *T. pearsei*	10.2000	1.000

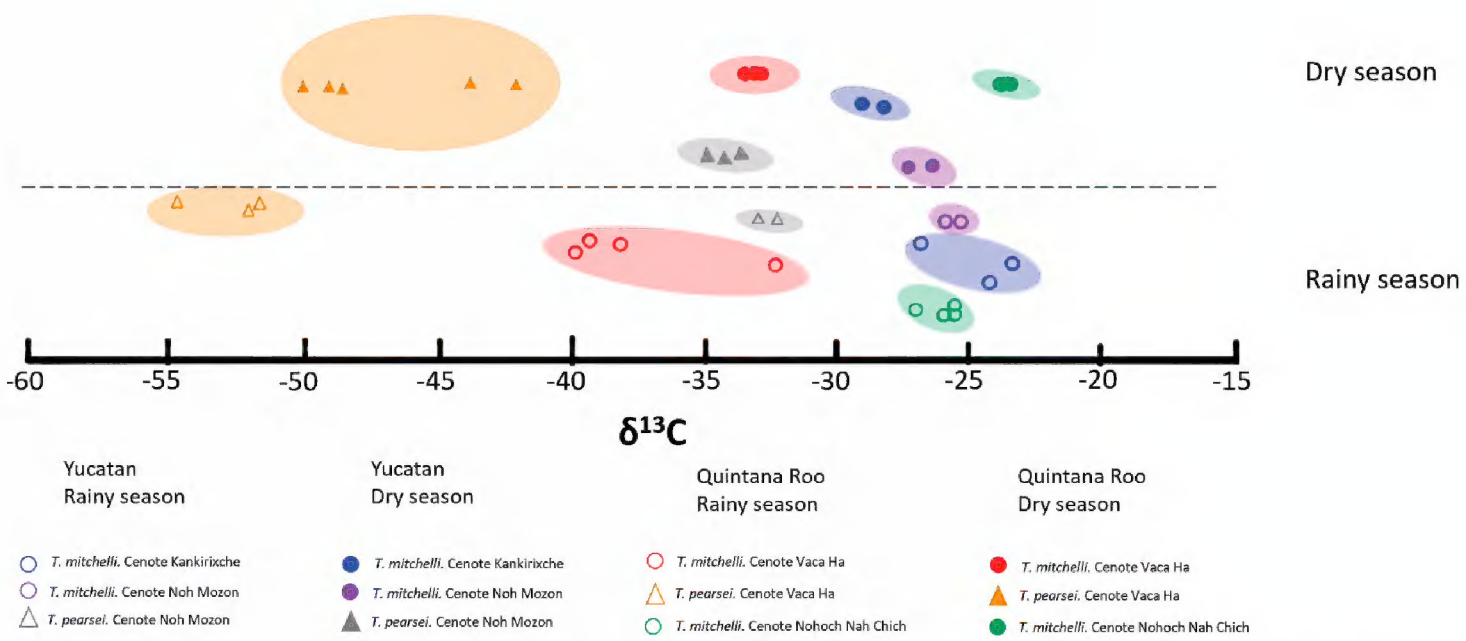

Figure 4. Rainy and dry seasons $\delta^{13}C$ values for *Typhlatya mitchelli* (circles) and *T. pearsei* (triangles) in four cenotes, dashed line separates the two seasons, color shading identifies each cenote.

co-occurrence of *T. mitchelli* and *T. pearsei.* The only $\delta^{13}C$ values available for *T. dzilamensis* come from Cenote Ponderosa in the Caribbean Cave Area (-31.26 to -43.78; Chávez-Solis et al. 2020).

The convex hulls for *T. mitchelli* and *T. pearsei* span a wide range of $\delta^{13}C$ (-22.31 to -55.48) and $\delta^{15}N$ (-0.56 to 14.12) values, with an overlap between -31 and -39 in $\delta^{13}C$ and 7 and 8 in $\delta^{15}N$ (Fig. 5). The overlap in the convex hull area corresponds to 23.05% for *T. mitchelli* and 17.62% for *T. pearsei*. Overall, *T. pearsei* shows broader carbon and nitrogen ranges and a larger total hull area than *T. mitchelli* (Table 3).

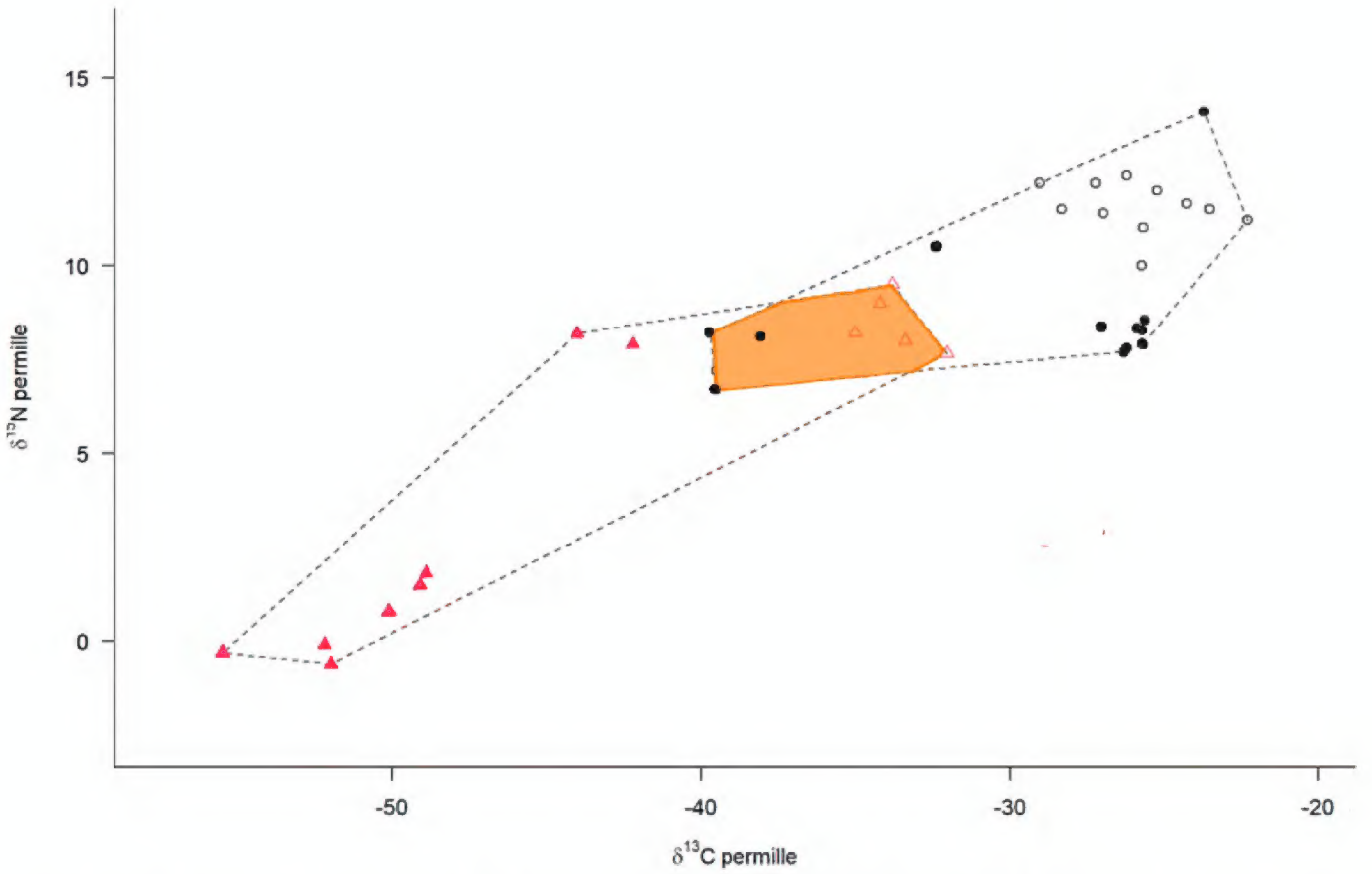

Figure 5. Bi-plot of $\delta^{15}N$ and $\delta^{13}C$ with the convex hulls of *Typhlatya mitchelli* (open circles = samples from the Ring of Cenotes; solid circles = samples from the Caribbean Cave Area) and *T. pearsei* (open triangles = samples from the Ring of Cenotes; solid triangles = samples from the Caribbean Cave Area). Shaded in orange is the overlap area of the two polygons.

Table 3. Layman metrics for *Typhlatya mitchelli* and *T. pearsei*. The percentage overlap represents how much of each of the two species total area overlaps with the total area of the other species.

	Typhlatya mitchelli	***Typhlatya pearsei***
Carbon range (CR)	17.4	23.43
Nitrogen range (RN)	7.4	10.10
Total area (TA)	62.865	81.8392
Percentage overlap	23.049	17.617
Mean distance to centroid (CD)	4.659408	8.693486
Mean distance to nearest neighbor (NND)	0.9452145	1.158355
Standard deviation of nearest neighbor distance (SDNND)	0.8077301	0.8240895

Discussion

The importance of the ecological role of *Typhlatya* shrimps in the anchialine ecosystem is becoming more and more evident (Brankovits et al. 2017; Durán and Álvarez 2025). Their large number of species, broad geographic distribution across oceanic islands and continental coastlines, high local abundance, long evolutionary history, and particular feeding mode, are some of the attributes that are pushing *Typhlatya* shrimps as key model species in the anchialine ecosystem (Brankovits et al. 2017; Jurado-Rivera et al. 2017; Álvarez et al. 2023; Trejo-Ventura et al. 2023). The Yucatán Peninsula, which harbours four species of *Typhlatya* (*T. campecheae*, *T. mitchelli*, *T. pearsei*, *T. dzilamensis*), is a unique region due to the vast extent of its anchialine cave networks that might exceed 1,700 km in Quintana Roo alone (QRSS 2025). Although the distribution patterns of these four species still need to be explored with detail in this vast ecosystem; the frequent sympatry of *T. mitchelli*, *T. pearsei*, and *T. dzilamensis* raises important questions regarding their resource use and trophic niche partitioning. *Typhlatya campecheae* is a rare species that has been collected only a couple of times, and no ecological or isotopic data exists, for that reason we have left it out of the discussion.

Benítez et al. (2019) offered a first spatial analysis of the three most common *Typhlatya* species within a single cave system, Ox Bel Ha (south of Tulum, Quintana Roo). They reported weak vertical zonation in the water column, with *T. mitchelli* and *T. pearsei* co-occurring at similar depths, and *T. dzilamensis* inhabiting deeper layers associated with the halocline. Chávez-Solís et al. (2020) found the same general pattern, compiling data from three different cenotes. All these studies suggested that the degree of spatial segregation among species varies depending on cave geomorphology, depth, extension, proximity to the coastline, and halocline depth, as well as the regional hydrogeological setting. Overall, available data suggest substantial spatial overlap among the three species.

Regarding the trophic specialization of each *Typhlatya* species, there is no clear pattern when we look at the data separately for each cenote. However, when all the available $\delta^{13}C$ data for the three species is considered, a clearer pattern starts to emerge adding to the idea that each one may occupy its own niche space (Figs 3, 5). *Typhlatya mitchelli* shows the least negative $\delta^{13}C$ values, consistent with feeding on decaying vegetation and on bacterial mats dominated by nitrifying bacteria in the shallower sections of caves. *Typhlatya dzilamensis*, typically associated with the halocline and prefering brackish to marine salinities, likely exploits food resources in deeper cave sections. The halocline traps imported organic material, which undergoes microbial processing by heterotrophic (-20 to -35; Peterson and Fry 1987), nitrifying (-35 to -45; Peterson et al. 1980), or methanotrophic bacteria. Such processes may generate the intermediate $\delta^{13}C$ values observed in this species. *Typhlatya pearsei*, in contrast, exhibits the most negative $\delta^{13}C$ values, consistent with grazing on higher fractions of methanotrophic biomass, likely supplemented by additional food sources (Durán and Álvarez 2025). This supports the model proposed by Brankovits et al. (2017), in which *Typhlatya*

shrimps feeding on methanotrophic biomass act as links transferring chemosynthetic production into the anchialine trophic web. In contrast, *T. pearsei* prefers shallower cave sections (Benítez et al. 2019), where methanotrophic biomass originates near the ceiling of the cave. Thus, previous hypotheses based solely on spatial segregation can now be complemented by clear trophic differentiation among species.

Support for trophic convergence in anchialine atyids comes from Australia. *Stygiocaris stylifera*, closely related to *Typhlatya* (Botello et al. 2013; Jurado-Rivera et al. 2017) and endemic to the Cape Range Peninsula and Barrow Island (Page et al. 2008), displays $\delta^{13}C$ values (-27 to -30) and $\delta^{15}N$ values (4–6) indicative of partial reliance on chemoautotrophic bacterial biomass (Humphreys 1999). This parallel evolution of bacterial-based feeding strategies in distant atyid lineages suggests that the ability to exploit chemoautotrophic production may help explain the persistence of anchialine systems as ecological refugia over geological timescales (Iliffe et al. 1983, 2025; Jurado-Rivera et al. 2017). The versatile feeding apparatus of atyids likely facilitates this opportunistic strategy.

Brankovits et al. (2018) reported an inverse relationship between methane concentration and rainfall in an inland cenote of the Ox Bel Ha system. Based on this, we hypothesized that seasonal variation in methane concentration would influence the $\delta^{13}C$ signatures of *Typhlatya* shrimps. However, our comparisons from four cenotes, two in the Ring of Cenotes and two in the Caribbean Cave Area, showed no significant differences (Fig. 4). These results should be interpreted cautiously. Brankovits et al. (2018) examined a single site (Cenote Bang) during 2015–2016, whereas our samples were obtained in 2022–2023 from geographically distant cenotes. Larger, standardized datasets collected simultaneously across sites will be required to determine whether seasonal methane variation consistently affects shrimp isotopic signatures.

Regarding our $\delta^{15}N$ results, it has been shown that $\delta^{15}N$ values typically increase at higher trophic levels or under eutrophic conditions (Aita et al. 2011). Conversely, nitrogen-limited freshwater systems, such as phreatic waters in anchialine caves, can yield relatively low $\delta^{15}N$ values in primary consumers due to efficient nitrogen recycling (Bunn et al. 2013). The broad $\delta^{15}N$ ranges observed for *T. mitchelli* (6.65–14.12) and *T. pearsei* (-0.56–10.02), likely reflect on the one hand, their variable diet and the variable origin of the microbes they are grazing on, and on the other hand, the geographic location.

Flooded caves in the Yucatán Peninsula have different geomorphologies and hydrological conditions depending on the regional context. The Ring of Cenotes forms an arch around Mérida, with generally deeper caves, limited water movement, and relatively short, unconnected passages. In contrast, the Caribbean Cave Area in Quintana Roo contains shallower caves with tens to hundreds of kilometers of interconnected passages and strong lateral flows (Álvarez et al. 2023). Despite these differences, the same three *Typhlatya* species occur across both regions, allowing a comparison of geographic effects on the anchialine trophic web structure. Caves in the Ring of Cenotes exhibit narrower $\delta^{13}C$ ranges, likely reflecting a stronger dependence on particulate organic matter entering directly from surrounding vegetation (Fig. 2). The more restricted horizontal development of these caves limits the amount of surface-derived organic matter available. In contrast, the extensive cave networks from the Caribbean

Cave Area create extensive areas of surface influence. Organic matter from the overlying rainforest percolates through the rock matrix, generating small amounts of methane that are oxidized by methanotrophic bacteria near cave ceilings (Brankovits et al. 2017). These bacteria provide an additional basal resource that complements direct organic inputs. Accordingly, anchialine communities in this region show broader $\delta^{13}C$ ranges, consistent with mixed reliance on particulate organic matter and methanotrophic biomass. This process, depends on the integrity of the rainforest, which is crucial to maintain the rich anchialine fauna in remote sections of the caves where organic matter from the surface is not transported.

Finally, the convex hulls analyses illustrate the breadth of the isotopic niches of *T. mitchelli* and *T. pearsei*. *Typhlatya mitchelli* integrates carbon from allochthonous organic matter, associated microbial biomass, and dissolved organic carbon, whereas *T. pearsei* incorporates a substantial component of methanotrophic production (Fig. 5). The overlap between species, around 20%, occurs at $\delta^{13}C$ values of -33 to -40, suggesting a transition between the two primary feeding strategies. Geographic patterns are also evident. Samples taken from the Ring of Cenotes region show less negative $\delta^{13}C$ and higher $\delta^{15}N$ values, whereas those from the Caribbean Cave Area display the opposite trend (Fig. 5). The breadth of the isotopic niches of the two species underscore their trophic importance, the diversity of resources they exploit and the influence of regional geomorphological differences. Continued study of *Typhlatya* shrimps will further illuminate the functioning of this still poorly known ecosystem.

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Supplementary material 1

Isotopic values of $\delta^{13}C$ and $\delta^{15}N$

Authors: Brenda Durán, Fernando Álvarez

Data type: docx

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Supplementary material 2

Wilcoxon signed-rank test ($p > 0.05$)

Authors: Brenda Durán, Fernando Álvarez

Data type: docx

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